City of Guelph

IWA / AWWA Water Audit and Water Balance

2006 & 2007 Reports

June 18th, 2008

Prepared by:

HETEK SOLUTIONS INC.

TABLE OF CONTENTS

IWA Water Balance and Performance Indicators

				Date	**13/06/2008**	
Study Area	**Guelph**			Input by:	**DP**	
Study Period	**April 07 - Mar 08**			Key	Data entry	
					Other Sheet	
Water Balance				**Av daily Volume Ml/d**	**95% Confidence**	**Variance**
Water produced at treatment works		Meter **over** registration	-0.93%	51.5	1%	0.069
Water Imported		Meter **over** registration	0.00%	0.00	1%	0.000
	System Input Volume			51.48	1%	0.069
Water Exported		Meter **over** registration	0.00%	0.00	4%	0.000
	Water Supplied			51.48	1%	0.069
Billed Household Metered						0.000
Billed Non-Household Metered						0.000
Billed Metered consumption				43.19	2%	0.194
Billed Unmetered consumption				0.06	20%	0.000
	Revenue Water/Billed Authorised Consumption			43.24	2%	0.194
	Non-Revenue Water			8.23	12%	0.263
Unbilled authorised metered consumption				0.00	20%	0.000
Unbilled authorised unmetered consumption				0.19	30%	0.001
	Unbilled Authorised			0.19	30%	0.001
	Authorised consumption			43.44	2%	0.195
	Water Loss			8.04	13%	0.264
Household metering losses		Meter **under** registration		0.00		0.000
Non Household metering losses		Meter **under** registration		0.00		0.000
		Meter **under** registration	4.63%	2.10	25%	0.072
Unbilled unauthorised consumption		Default AWWA%WS	0.50%	0.26	100%	0.017
	Apparent Losses			2.4	25%	0.089
	Real Losses (CARL)			5.7	20%	0.353

Network data		Value	**95% Confidence**	
Length of mains	km	524	2%	28.59
Number of connections	no	34971	3%	286514
Number of services	no	34971	2%	127340
Connection ratio		1.0	4%	0.000
Connection density	no/km	67	4%	1.507
Av length of UGSP	m	9.8	10%	0.25
Total UGSP length	km	343	10%	318
Average Pressure	psi	60	10%	9.37
	m	42	10%	4.63
Hour to Day Factor	hrs	24	10%	1.50

UARL	**Ml/d**	**95% Confidence**	
Mains	0.40	10%	0.0004
Connections	1.18	10%	0.0040
Properties	0.36	14%	0.0007
Total	1.9	7%	0.0051

IWA System Performance Indicators				**95% Confidence**	
Non Revenue Water		% of SIV	16%	12%	0.000
		% of WS	16%	12%	0.000
Real Losses	TIRL	l/conn/d	160	21%	295
Real Losses	ILI		2.9	22%	0.105

1.0 INTRODUCTION AND APPROACH

As part of its ongoing efforts to control water loss in their distribution system and to reduce the levels of non-revenue water, the City of Guelph completed water balances on their water distribution system in 2006 and 2007. Using the American Water Works Association (AWWA) and International Water Association (IWA) water audit and balance methodology, HETEK Solutions Inc., and Dave Pearson have conducted an in depth analysis on these water balances to identify and obtain the areas where additional information can be included, as well as to provided confidence limits on the gathered data.

Through a series of meetings with City staff, the AWWA / IWA water audit approach and methodology was established and a series of questions for the missing data was distributed to the appropriate people. City staff was extremely supportive of the project, and provided excellent data in a very timely manner. The efforts of Wayne Galliher, John-Paul Palmer, Walter Maggiola, Vince Suffolletta, Gerry Best, Brian van Nostrand, and John Michalofsky was very much appreciated.

The process of gathering data was multi-staged, and as information was obtained it was recorded on the questionnaire, and areas where more information was required were identified. Subsequent data provided by City staff was again recorded on the questionnaire until all the required information was eventually obtained.

The gathered data for both 2006 and 2007 was next entered into a series of spreadsheets. In each annual spreadsheet the individual areas of water use were identified and the volumes of water use were recorded. Finally the total volume of water use per year was calculated for each of the AWWA / IWA water balance categories.

Two AWWA / IWA water balance software programs along with Dave Pearson were used to analyse the gathered data:

- AWWA Water Loss Control Committee (WLCC) Water Audit Software v3.0
- WB-EasyCalc version 1.18 by Liemberger & Partners
- Dave Pearson is a chartered engineer with a BSc in Civil Engineering and a Diploma in Water Engineering. With 33 years of water loss experience, David is a key member on the IWA Water Loss Task Force with a focus on both the economics of leakage control and the control of apparent losses.

For each software program, the data from the series of spreadsheets was entered into the appropriate fields. The results obtained from the two software programs and Dave Pearson was similar.

These results, along with the information gathered about the City of Guelph's water system, were used to develop recommendations for a long term water loss program.

2.0 AWWA/IWA WATER AUDIT AND BALANCE METHODOLOGY

The IWA / AWWA water balance identifies categories of Revenue and Non Revenue water from the water supplied to a system. Revenue water can either be metered or non metered. There is a range of different types of Non Revenue Water (NRW) that may or may not be significant for each individual supplier of water. They have been summarised in the following three categories by the IWA / AWWA methodology:

2.1 Unbilled Authorised Consumption

Unbilled metered

Unbilled unmetered

The following uses are unbilled and can be metered or unmetered, according to local practice:

- Fire fighting
- Flushing of mains and sewers
- Cleaning storage tanks
- Filling water tankers
- Water taken from hydrants
- Street cleaning
- Parks irrigation
- Public fountains
- Frost protection
- Building water for construction

2.2 Apparent Losses

Unauthorised consumption

Theft

- Not opening an account
- Self connecting / disconnecting meter
- Tampering with meter or remote
- Use of false names
- Illegal connections and by passes
- Unauthorised use of fire hydrants

Detecting theft

- Active accounts with no usage
- Inactive accounts with usage
- Periodic review of all inactive accounts
- Meter reader observations
- Inspection of unmetered fire lines
- Review of billing records

Metering inaccuracies

System input meters

- Details of meters, and calibration history

Under / over registration of customer meters

- Any testing of commercial or residential meters

Accounting procedure errors

- Difference between dates of source meter readings and customer readings
- Identify accounts not being billed – quantify reasons why
- Identify active accounts with no consumption for the last 6 months, could be stuck meter, remote problem or theft
- Identify inactive accounts with usage (occupied, but not opened an account or vacant with leakage)
- Misread meters
- Incorrect estimates
- Stopped meters – particularly compound meters (stuck small side – all usage on large side; stuck large side, with most usage on small side)
- Stopped meters – track monthly revenue changes, versus same month in previous year
- Adjustments to original meter readings
- Unit conversions
- Improper calculations
- Computer programming errors

2.3 Real Losses

Leakage on distribution and transmission mains

- Holes and cracks in mains
- Joints
- Drain valves left open, leaking

Leakage and overflows at storage tanks

- Buried reservoirs structures
- Drain valves left open, leaking
- Overflows

Leakage on service connections up to the point of customer metering

- Holes in service pipes
- Joints

2.4 Definitions

It is the Real Losses that the leak detection techniques target, referred to as CARL (Current Annual Real Losses). Within these Real Losses there is a volume of water that is unavoidable, even with the most comprehensive leak detection program – this is called UARL (Unavoidable Annual Real Losses). So the difference between CARL and UARL, is the Real Losses that is targeted for reduction. This difference, or ratio of CARL to UARL is referred to as the ILI (Infrastructure Leakage Index).

For the management of these Real Losses, there are four areas to look at. They are as follows:

- Active leak detection
- Speed and quality of repairs
- Pressure management
- Pipeline and asset management

3.0 DATA GATHERING

The first stage of the data gathering exercise was to provide a detailed questionnaire to City staff, which had the purpose of informing them about the type of information, and the level of detail that would need to be gathered. This was sent ahead of the first series of meetings. The questionnaire provided in detail the information requirements from the following departments in the IWA audit areas:

Operations Department

(a) Water Supplied Data
1. Volumes of water supplied from all sources
2. Accuracy of source meters

(b) Non-revenue Water – Unbilled Authorised
1. Flushing of mains and sewers (indicate if data is metered or estimated)
2. Cleaning of storage tanks - indicate how data is tracked
3. Filling of water tankers
4. Water taken from hydrants (indicate how data is tracked)
5. Water used for street cleaning (indicate how data is tracked)
6. Frost protection (if applicable)
7. Building water for metered and un-metered sites
8. Blow offs
9. Water main repairs and flushing
10. Unavoidable annual real losses (UARL)
11. Potential for water loss reduction

Billing Department

(a) Revenue Water – Billed Authorised – Water Billing Data
1. Residential accounts

2. ICI accounts

(b) Non Revenue Water – Apparent Losses
1. Theft
2. Customer meters

Fire Department
Non-revenue Water – Unbilled Authorised

Engineering / Infrastructure Department
Water Distribution System Infrastructure
1. Water mains
2. Service mains

Parks Department
Non-revenue Water – Unbilled Authorised
1. Parks irrigation
2. Public fountains

4.0 SUMMARY OF DATA GATHERED

Meetings took place with Guelph City staff in April, 2008. During these meetings some of the data was provided in hard copy and some in electronic format. The gathered data was then summarized and entered into a series of spreadsheets. Information that was not available at this time was obtained and sent over the next month. The vast majority of this information was provided by mid March, 2008.

The spreadsheets were developed to match the IWA software data entry pages with the summary and totals shown below:

2006 IWA Balance Item	Volume / Year (m^3)
Annual Water Pumped	18,756,338
Source Meter Inaccuracies (0.93% under registering)	174,434
Bulk Water Supply Export and Import	0
Billed Metered Consumption	15,923,355
Billed Unmetered Consumption	15,912
Unbilled Metered Consumption	0
Unbilled Unmetered Consumption (Operations)	48,207
Unbilled Unmetered Consumption (Watermain Installs)	2,868
Unbilled Unmetered Consumption (Fire Department)	2,898
Unauthorised Consumption (0.50% of system input)	94,653
Number of Customer Meters	34,065
Customer Meter Inaccuracies (under registering)	4.63%

Length of Network - Mains	517 km
Avg. Length of Services (Curb Stop to Customer Meter)	9.8 meters
Pressure in Distribution System	42 m
Financial Data - Customer Rate per m^3 of water	$0.690
Water Production Cost per m^3	$0.1889
Variable Production Cost per m^3 of water	*$0.0612*
Fixed Production Cost per m^3 of water	*$0.1277*
Total Annual Cost of Operating Water System	$3,542,937

See attached spreadsheet for details on gathered data.

2007 IWA Balance Item	**Volume / Year (m^3)**
Annual Water Pumped	18,616,944
Source Meter Inaccuracies (0.93% under registering)	173,138
Bulk Water Supply Export and Import	0
Billed Metered Consumption	15,763,551
Billed Unmetered Consumption	20,800
Unbilled Metered Consumption	0
Unbilled Unmetered Consumption	71,930
Unauthorised Consumption (0.50%)	93,950
Number of Customer Meters	34,971
Customer Meter Inaccuracies (under registering)	4.63%
Length of Network - Mains	524 km
Avg. Length of Services (Curb Stop to Customer Meter)	9.8m
Pressure - in Distribution System	60 psi / 42.21 m
Financial Data - Customer Rate / m^3 of water	$0.75
Water Production Cost per m^3	$0.1889 / m^3
Variable Production Cost per m^3 of water	$0.0612
Fixed Production Cost per m^3 of water	$0.1277
Total Annual Cost of Operating Water System	$3,516,606

5.0 IWA SOFTWARE ANALYSIS FOR 2006

Two IWA water balance software programs were used to analyse the gathered data for 2006. The results of the analysis are given below:

5.1 AWWA (WLCC) Water Audit Software v3.0

The full analysis results for the AWWA-WLCC program are provided in Appendices 2 and 3 and are summarised below. Note all volumes for this program are entered as Megalitres (thousand cubic meters) per year.

Parameter	Value
Current Annual Real Losses (CARL)	2,069 ML
Unavoidable Annual Real Losses (UARL)	688 ML
Infrastructure Leakage Inde200x (ILI)	3.01 ILI
System Input Volume	*18,930.7 ML
Revenue Water	15,939 ML
Non-Revenue Water	2,991.5 ML
Volume of Non-Revenue Water - % of System Input Volume	15.8%

*this number includes 1% source meter under-register.

5.2 WB-EasyCalc Version 1.18 by Liemberger & Partners

The full analysis results for the WB-EasyCalc program are provided in Appendices 4 and 5 and are summarised below:

Parameter	Value
Current Annual Real Losses (CARL)	2,069,005 m^3
Unavoidable Annual Real Losses (UARL)	688,377 m^3
Infrastructure Leakage Index (ILI)	3.0 ILI
System Input Volume	18,930,772 m^3
Revenue Water	15,939,267 m^3
Non-revenue Water	2,991,505 m^3
Volume of Non-revenue Water - % of System Input Volume	15.8%

6.0 IWA SOFTWARE ANALYSIS 2007

The same two IWA water balance software programs were used to analyse the gathered data for 2007. Both system input volumes include the 1% source meters under-registration. The results of the analysis are given below:

6.1 AWWA (WLCC) Water Audit Software v3.0

The full analysis results for the AWWA-WLCC program are provided in Appendices 6 and 7 and are summarised below. Note all volumes in this program are entered as Megalitres (thousand cubic meters) per year.

Parameter	Value
Current Annual Real Losses (CARL)	2,073 ML
Unavoidable Annual Real Losses (UARL)	705 ML
Infrastructure Leakage Inde200x (ILI)	2.94 ILI
System Input Volume	18,790 ML
Revenue Water	15,784 ML
Non-Revenue Water	3,001 ML
Volume of Non-Revenue Water - % of System Input Volume	16%

6.2 WB-EasyCalc Version 1.18 by Liemberger & Partners

The full analysis results for the WB-EasyCalc program are provided in Appendices 8 and 9 and are summarised below:

Parameter	Value
Current Annual Real Losses (CARL)	2,073,352 m^3
Unavoidable Annual Real Losses (UARL)	704,823 m^3
Infrastructure Leakage Index (ILI)	2.9 ILI
System Input Volume	18,790,082 m^3
Revenue Water	15,784,351 m^3
Non-revenue Water	3,005,731 m^3
Volume of Non-revenue Water - % of System Input Volume	16%

7.0 IWA Software Analysis Summary

In any water system there will be a volume of leakage that includes small leaks and weeps that is either undetectable in practice, or not economic to find and repair – this is the Unavoidable Annual Real Losses (UARL). The IWA software uses the physical characteristics of the water distribution system (length of water mains and services, number of connections, average pressure) to make an estimate of UARL. The Current Annual Real Losses (CARL) are also calculated by the software, by taking the water supplied and deducting the calculated authorized consumption and apparent losses, to give CARL. The ratio of UARL to CARL is the Infrastructure Leakage Index (ILI).

The analysis from the two software programs has provided very similar results for each year. The performance indicator, Infrastructure Leakage Index (ILI) for 2006 is a value of between 3.0 and 3.01. For 2007, the City's ILI was in a slightly lower range value of 2.9 and 2.94. These performance indicators provide an indication of the level of real losses in the water distribution system as described above.

The World Bank Target Matrix for ILI shows the City of Guelph to be in the performance B category - Potential for marked improvements; consider pressure management, better

active leakage control practices, and better network management, as indicated in the following table:

ILI Range	Performance Category	Real Loss Management
1-2	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost effective improvement
2-4	B	Potential for marked improvements; consider pressure management, better active leakage control practices, and better network management
4-8	C	Poor leakage record, tolerable only if water is plentiful and cheap; even then, analyse level and nature of leakage and intensify leakage reduction efforts
>8	D	Very inefficient use of resources; leakage reduction programs imperative and high priority

8.0 RECOMMNEDATIONS

Based on the discussions with City staff, the data gathering process, and the analysis of the gathered data, the following recommendations have been made:

8.1 Customer Water Meters

The City of Guelph was fully metered in the late 1960's and today it is fitted with approximately 34,971 customer meters. In 2007, these customer meters recorded a consumption of 15,784,351 m^3 of water which generated $11,792,050 in revenue.

As meters get older, they generally begin to under register. For many years the City has been changing out their older problematic customer meters. However, when these meter replacements happen it is recommended that the removed meters be checked to understand their potential loss in revenue.

In the following chart it can be seen that if around 300 of the 34,971 meters were removed and tested for accuracy the results would provide a margin of error between 5% and 6%, with 95% confidence in the data.

Simple Random Sample							
With a 95% confidence level and 50% estimate of population proportion							
Meter Population size – error margin	**Unlimited**	**1,000,000**	**500,000**	**250,000**	**100,000**	**10,000**	**5,000**
1%	9,604	9,513	9,423	9,249	8,762	4,899	3,288
2%	2,401	2,395	2,390	2,378	2,345	1,936	1,622
3%	1,067	1,066	1,065	1,063	1,056	964	879
4%	600	600	600	599	597	566	536
5%	384	384	384	384	**383**	370	357
6%	267	267	267	266	**266**	260	253
7%	196	196	196	196	196	192	189
8%	150	150	150	150	150	148	146
9%	119	119	119	119	118	117	116
10%	96	96	96	96	96	95	94
11%	79	79	79	79	79	79	78
12%	67	67	67	67	67	66	66

Reference: Chakrapani: C&K Deal, Market Research: Methods and Canadian Practice, 1992

To obtain an understanding of the potential lost revenue and volumes of water involved with the customer accounts, the following table has been prepared. The customer billing rate used for the purpose of this chart is based on the average 2007 rate of \$0.75 per m^3 of water. This rate was determined by dividing the 2007 customer water revenue by the customer meter consumption.

Meter Size	**Number**	**Volume**	**Estimated Loss in Revenue / Year**		
		m^3 / Year	**4%**	**6%**	**8%**
		2006			
5/8" & 1/2"	34,971	15,784,351	\$473,531	\$710,296	\$947,061
		Volume	631,374 m^3	947,061 m^3	1,262,748 m^3

8.2 Leak Detection

The results from the IWA / AWWA water balances indicated that the City had an ILI in the 3.0 range for 2006 and a slightly lower ILI range of 2.9 in 2007. These annual ILI ranges place the City of Guelph in the World Bank performance category B - Potential for marked improvements; consider pressure management, better active leakage control practices, and better network management.

There are a number of options that can be used in an active leak detection program, they are as follows:

- **Sounding** of the fittings on the water distribution system, which traditionally has primarily been hydrants, and subsequently mainline valves and curb stops in areas where leaks are suspected. An enhanced method of sounding is to listen on a valve at all of the distribution main intersections, as well as hydrants. This generally enables more leaks to be found.

- **Temporary DMA's** (District Metered Area) where they are typically operated for a seven-day period initially, and the flows at night, between 2 a.m. and 4 a.m. (Minimum Night Flow - MNF) are compared to what flow would be expected from the area. Only in areas of high MNF are leaks looked for in a two step process – step one, narrow the leak down to the *General area of the leak*, and step two, *Pinpoint the leak* (blue cross on the ground). There are a number of methods employed to find the general area of a leak, which include night time step testing, when sections of the DMA are closed off for short periods, and the change in flow at the DMA flowmeter is inspected for high drops in flow, indicating a potential leak. Another method to find the general area of the leak is to use noise loggers, which are used to listen for leaks. Finally, the leak is pinpointed using leak noise correlators, and ground microphones to confirm the location of the leak. Temporary DMAs are typically operated once every one to two years

- **Permanent DMAs Used for Leak Notification**, are used where the DMA is permanently isolated from the rest of the distribution system, and night time flows are monitored on a daily basis. When the MNF reaches a predetermined level (Entry Level), then leak detection is completed in that DMA – *General Area of the leak*, and *Pinpointing the leak*. Leak detection and repair is continued until the leakage has been reduced to an acceptable amount (Exit Level), as recorded on the permanent DMA flowmeter

- **Permanent DMAs Used for Leak Notification and Pressure Management**, where in addition to the leak detection activities, pressure management is introduced. This is completed by installing a Pressure Reduction Valve (PRV), which is used to control the pressure so that during the "off peak" demand times, the pressure is not allowed to increase, and a less variable pressure is delivered to the DMA. This method of operation has the dual benefit of reducing background leakage (small leaks that are not economical to find and repair), and also reduces main breaks

The Best Management Practice (BMP) for active leak detection, which will form a principal part of the new AWWA manual, M36, is to complete District Meter Area (DMA) leak detection. It is therefore recommended that Temporary DMAs be established in the City of Guelph as the key element of the active leak detection program.

8.3 IWA Water Audit and Water Balance

It is also recommended that the IWA water audit and water balance be repeated every year, and the results of the implementation of the various measures outlined in this report can be included in the new balance each year, along with changes in revenue and non-revenue water in the City of Guelph.

9.0 DAVE PEARSON'S WATER LOSS STUDY

9.1 INTRODUCTION

This report describes the results of a water loss study carried out for the City of Guelph, Ontario.

The study has involved the following steps:

- Assessment of losses using the standard IWA water balance methodology
- Assessment of key performance measures using IWA methodologies
- Review of the potential for real losses reduction

9.2 THE IWA WATER BALANCE METHODOLGY

The first step in the assessment of the actual losses on a system is to use a consistent and reliable methodology. To this end the IWA Water Loss Task Force (WLTF) defined a standard methodology (Ref 1). This methodology is summarised in Appendix 1. The methodology has now been recommended by the AWWA and is being adopted across North America as the standard method for assessing losses. The standard IWA water balance approach and methodology has been used to assess the real and apparent losses from the distribution system at Guelph. An estimate of the confidence level of the assessment has also been included. In addition the standard IWA performance measures (Ref 2), and in particular the Infrastructure Leakage Index (Ref 2), have also been assessed.

9.3 DATA AND ASSUMPTIONS

The data for the system water balance have been supplied by the City of Guelph. The information obtained includes:- System Input Volume (water produced at the source), the metered volume supplied to Commercial and Residential customers served, water taken unbilled (for such activities as municipal watering and fire fighting) and asset information on the length of mains and the number of connections.

9.3.1 Water Produced/System Input Volume

Water is supplied into the system from the water sources. There are no further imports of water so System Input Volume and Water Produced are one of the same. The water source meters, which are generally full bore mag meters, are checked regularly. A survey has been carried out to evaluate potential bias on the meters and the results of this study have been made available in a separate report. This study showed a range of bias between ~-4% to ~+4%. The average bias taking into account the relative volume through the

different meters is -0.93% i.e. the meters are under recording actual output by 0.93%. Woods Reservoir discharge is the predominant meter. The confidence level of the measurement has been taken to be +/-1% based on the quality of the meters.

9.3.2 Water Exported/Water Supplied

There are no exports from the Guelph operating network to other municipalities. Water Supplied is therefore the same as Water Produced and System Input Volume. This is the water supplied to the City of Guelph network.

9.3.3 Billed Water

Water is billed through revenue meters on customer premises. It is common for revenue meters to under record actual consumption as the meters wear. The meter under recording has been estimated and this is reported in a separate report. Based on these figures, weighted for the volume and the age of the meter, it is estimated that meter under registration is 4.63%. It is estimated that the confidence level of this assessment is +/-25% since it has not been based on actual meter studies of Guelph meters taken out of service and placed on a calibration test bench. It has been estimated that the confidence level of the actual volume recorded is +/-2% taking into actual installation situations and the variability between actual meters.

9.3.4 Unbilled Water

There are a number of unbilled uses on the network ranging from, for example, fire fighting and training, to mains flushing and municipal use. These are legitimate authorised uses and can be deducted from the water supplied. Although the best effort has been made to estimate these volumes there is, by their nature, a low degree of confidence to the estimates and so a confidence level of +/-30% has been attributed to these estimates.

9.3.5 Unauthorised use

No attempt has been made to estimate the volume lost to unauthorised use such as theft, illegal/unknown connections, fraud and billing system errors etc. For the purpose carrying out the water balance the AWWA default of 0.5% of Water Supplied has been assumed. Because this is a default value and there is no local information available on unauthorised use a low level of confidence of +/-100% has been assumed for this value.

9.3.6 Asset Data

In addition to the supply and consumption data, information was also supplied to assist in the assessment of the standard IWA water loss performance measures. This involved asset data which is summarised in Table 1.

Component	Unit	Value
Length of mains	km	524
Number of connections	no	34971
Number of services	no	34971
Connection ratio		1
Connection density	no/km	67
Av length of UGSP	m	9.8
Total UGSP length	km	343
Average Pressure	psi	60
	m	42
Hour to Day Factor	hrs	24

Table 1 Summary of Asset Data

The 95% confidence level were attributed to this data as follows – mains length and service connections 2%, number of connections 3% (on the basis that there may be some shared services), average length of service pipe 10% and average pressure 10%.

9.4 RESULTS OF THE IWA WATER BALANCE AND KPI's

The data obtained from the City was entered into a standard analysis sheet for the IWA water balance. The results of the analysis for 2006 data are attached in Appendix 10 and for 2007 in Appendix 11.

The analysis in Appendix 11 (2007) shows that Non Revenue Water is estimated at 8.2Ml/d, equivalent to 16% of System Input Volume or Water Supplied.

Part of Non Revenue Water is unbilled but authorised use (e.g. fire fighting etc) leaving losses of 8.0Ml/d. The allowance for revenue meter under-registration represents some 2.10Ml/d and the default allowance for unbilled unauthorised use of 0.5% of Water Supplied amounts to 0.26Ml/d. The sum of these two allowances (2.4Ml/d) is referred to as Apparent Losses. This leaves Real Losses at 5.7Ml/d.

Before discussing the interpretation of these figures it is necessary to review the performance indicators that are used to compare and understand leakage levels.

9.5 UNDERSTANDING AND COMPARING LEAKAGE LEVELS

Comparing the leakage performance of different water utilities can be problematical. It is common in many industries for wastage to be expressed as a percentage of the turnover of the product. This measure is often used by the media to compare performance on leakage as the measure is relatively easy to calculate and is understood by non specialists. However it has a major drawback in that the leakage from a distribution system is independent of the consumption unlike most other products (e.g. levels of shoplifting of retail goods). Consumption is very much a function of demand and plumbing practices in countries (e.g. toilet tank volumes) and can vary dramatically. It is common for consumption to vary by up to two or three times between countries because of cultural or climatic factors (such as garden watering) and therefore their leakage levels, when expressed in percentage terms, vary significantly. An alternative performance indicator

based on loss per property was suggested in early reports on leakage. However this performance can be sensitive to the density of the network. In water utilities with low density of connections losses per km of mains is more appropriate.

The use of different comparative performance measures was reviewed during the Managing Leakage work carried out in the UK (Ref 4).This work reinforced the deficiencies of the existing measures but at that time did not resolve the issue nor make recommendations on a reliable measure. The German Standard (Ref 5) recommends the use of losses per km of main, however it is generally accepted (Refs 2 and 6) that the use of losses per km is inappropriate in all but the most rural of networks (service connection density of less than 20 connections per km). Where connection density is greater than 20/km then a more sensible measure is losses per connection. This has been recommended by the IWA and adopted as their level 1 measure. It is referred to as the Technical Indicator of Real Losses (TIRL).

Work carried out by the IWA Water Losses Task Force (WLTF) (Ref 2) has recommended the use of an Infrastructure Leakage Index (ILI) to compare water utility performance. This measure has been specifically designed to be robust when used in different countries with different plumbing arrangements, different connection densities and different operating pressures.

In order to develop this international comparator the IWA WLTF introduced the concept of the unavoidable real losses (UARL) on a system. These losses were defined as those losses that could be expected from a well managed system in good condition. These losses are estimated using the component loss methodology with assumed values for the condition of the assets, burst frequencies, flow rates and durations. These values were developed by looking for the "best" values across a large number of companies internationally. No view was taken on operating pressure as it was considered that this would be company specific, related to the topography of the network.

Using the recommended values for infrastructure condition, burst frequencies, flow rates and durations, the UARL can be shown to be (Ref 2):

$$UARL = (18 * L_M + 0.80 * N_C + 25 * L_S) * AZP \quad (l/d)$$

Where: L_M = Length of mains (km)

N_C = Number of connections

L_S = Total length of supply pipe (km)

AZP = Average zone pressure (m)

A comparative leakage performance indicator is then calculated by expressing current actual real losses (CARL) as a ratio of the unavoidable losses. This indicator is referred to as the Infrastructure Leakage Index (ILI).

$$ILI = CARL / UARL$$

The IWA tested this indicator on a number of systems (Ref 2). This work showed that, generally speaking, most countries and systems had an ILI greater than 1 (see Fig 3).

Only the Netherlands had an ILI less than 1. Most systems that could be considered to be well managed with active leakage management were in the range 1 to 2. Systems with no active leakage programme and poor asset condition could have ILI's greater than 10.

9.6 INTERPRETING THE RESULTS FOR GUELPH

The results of analysis for Guelph for the measures discussed in the previous section are summarised in Table 2.

Component	Units	Value	95% CL
NRW	Ml/d	8.2	12%
NRW	%SIV	16%	12%
NRW	%WS	16%	12%
CARL	Ml/d	5.7	20%
UARL	Ml/d	1.9	7%
ILI		2.9	22%
TIRL	l/conn/d	160	21%

Table 2 Results of IWA losses and performance indicators

9.6.1 Confidence of assessment

Table 2 shows the results of the analysis together with the 95% confidence levels. The probability distribution functions of UARL and CARL are shown in Figure 2. This clearly indicates that CARL is always significantly higher than UARL even allowing for the uncertainties in the data and the assumptions used in the calculations. This indicates that there is leakage on the system and that there should be potential for reducing this leakage.

Appendix 11 shows that the poor confidence level of the assessment of CARL, and hence all the performance indicators, is primarily due to the uncertainty in the measured consumption (a variance of 0.2 out of a total variance of 0.35). The next most critical elements are the uncertainty in the estimated of customer meter under-registration (a variance of 0.07) and the uncertainty in the volume produced at the sources (variance of 0.07). This indicates that effort should to be expended in improving the confidence level of the customer revenue meter and the supply meters in order to improve the confidence level of the results of the analysis. The analysis shows that although the confidence level on unauthorised use is very high at 100% the variance is low because of the small volume. There is therefore little value in expending much effort in establishing a better estimate of this value at this time.

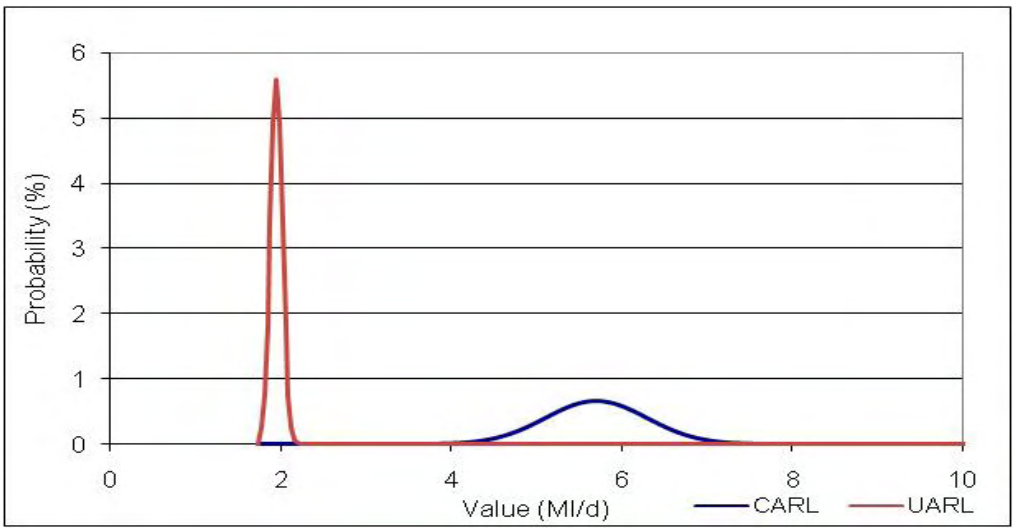


Fig 2 Probability distribution of CARL and UARL

The relatively good confidence level in UARL is due to the fact that this is assessed from physical data (e.g. length of mains and number of connections) which are reasonably well defined.

9.6.2 Infrastructure Leakage Index

The results of the analysis of the ILI for Guelph are shown in Table 2. This shows that ILI was assessed as 2.9. Figure 3 shows this in comparison to the original IWA sample.

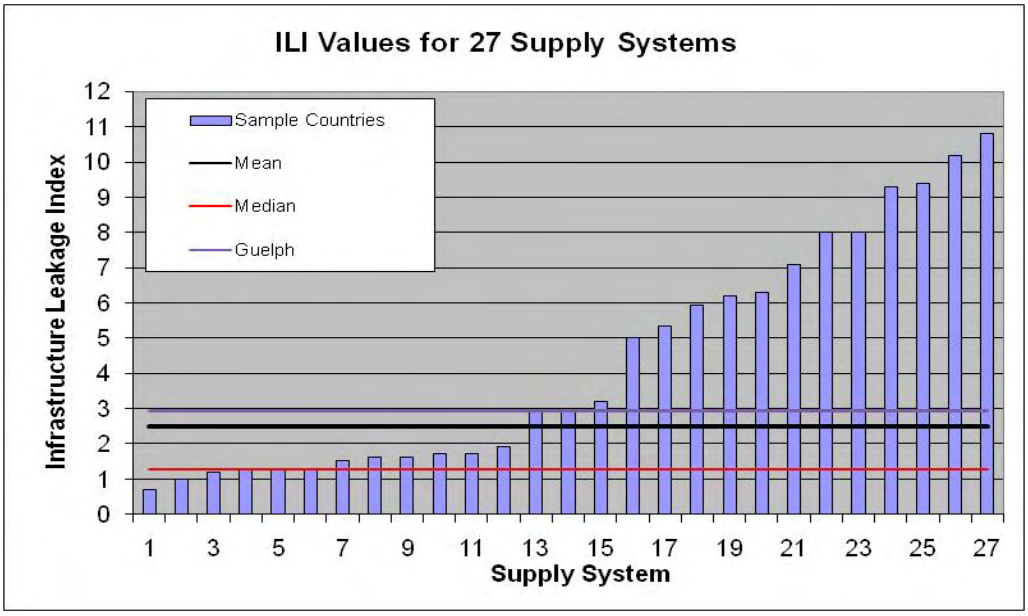


Fig 3 Infrastructure Leakage Index compared to sample of 27 countries

The World Bank (Ref 7) has adopted the ILI as a measure for the assessment of leakage performance. Table 5 shows their classification.

	Technical Performance Category	ILI
Developed Countries	A	1 - 2
	B	2 - 4
	C	4 - 8
	D	>8
Developing Countries	A	1 - 4
	B	4 - 8
	C	8 - 16
	D	>16

Table 5 World Bank Classification of leakage performance using ILI

The interpretation of the performance categories is as follows:-

Category A: *Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost effective improvement*

Category B; *Potential for marked improvements; consider pressure management, better active leakage control practices and better network maintenance*

Category C: *Poor leakage record; tolerable only if water is plentiful and cheap; even then analyse level and nature of leakage and intensify leakage reduction efforts*

Category D: *Horrendously inefficient use of resources; leakage reduction programmes imperative and high priority*

Using these classifications then the interpretation of the ILI for Guelph is:
Category B i.e**. Potential for marked improvement**. This indicates that there will be benefit from active leakage management.

9.6.3 Losses per connection (TIRL)

The losses for Guelph expressed as losses per connection (see Table 2) are 160l/conn/d. This performance measure can be assessed based on a table given in the German National Report (Ref 6). Basically this measure can be interpreted as indicating low leakage if TIRL<48l/conn/day, high if TIRL>96l/conn/d and medium if between these levels. Using this categorisation then the leakage level in Guelph would be considered **high.**

9.6.4 Comparison between 2006 and 2007

The results for 2006 and 2007 are compared in Table 6. This shows that there was a small deterioration in the value of real losses but ILI has in fact fallen slightly. This is explained by the fact that the size of the network has increased and that UARL has therefore increased. This means that the small increase in real losses can be explained by the increase sized of the network and therefore that leakage has not deteriorated but in fact has improved slightly.

Component	Units	2006	2007
NRW	Ml/d	8.2	8.2
NRW	%SIV	16%	16%
NRW	%WS	16%	16%
CARL	Ml/d	5.6	5.7
UARL	Ml/d	1.9	1.9
ILI		3.0	2.9
TIRL	l/conn/d	170	160

Table 6 Comparison of results for 2006 and 2007

9.6.5 Conclusions

It is concluded that the losses at Guelph are high. The Infrastructure Leakage Index performance measure at 2.9 would indicate that there is scope for reducing leakage. It indicates that there is likely to be economic as well as security of supply benefits in carrying out leakage management activities.

9.7 POTENTIAL FOR REAL LOSS REDUCTION

The potential for the management of leakage has been estimated under four areas:

- Proactive leakage detection
- Pressure management
- Rehabilitation
- Sectorisation

9.7.1 Proactive leakage detection

As an initial indication of the potential savings from proactive leakage control it should be assumed that ILI could be reduced to 1.5. This would mean that losses should be reduced to the order of 2.9Ml/d. This implies that reductions of approximately 2.8Ml/d in leakage could be achieved. This is equivalent to 5% of the output water supplied to the Guelph network. This would represent a saving of just over $60,000 per year on the production of water from the sources. This activity would include proactive detection to locate long running leaks.

9.7.2 Pressure management

Pressure management is the most cost effective method of reducing leakage. The indicated average pressure of 62 psi is not particularly high and it may not be feasible to reduce this significantly. If pressure could be reduced by 10% to 56psi then it is estimated that leakage would be reduced by 0.4Ml/d.

Pressure reduction to 56 psi would reduce the UARL by about 0.2Ml/d and the “target” level of leakage suggested in the section above (i.e. ILI=1.5) to 2.7Ml/d. This would represent a reduction 3.0Ml/d on current leakage levels equivalent to 6% of the source output and system input respectively. This would be equivalent to a saving of just over $65,000 per annum on the cost of producing water at the sources.

9.7.3 Rehabilitation

The mains bursts of 58 burst a year (based on repairs in 2007) equates to a frequency of 111bursts/1000km/yr. This is lower than the "good" condition burst frequency used by the IWA which is 130bursts/1000km/yr. It is therefore highly unlikely that any form of rehabilitation will be economic in Guelph, except perhaps a very limited level of rehabilitation in the older part of the city if the burst occurrences are concentrated in this area. Service pipe failures of 32 per year equate to 0.9 burst/1000conn/yr. This is significantly lower than the IWA good condition (3bursts/1000conn/yr) and would indicate that, if this is correct, then the service pipes are in very good condition.

9.7.4 Sectorisation

In the UK, supply areas are sectored and nightlines are monitored continuously and used to target leakage detection activity. Also, the whole network is covered by zonal monitoring. This has the advantage that it is possible to compare the leakage assessed from summing the leakage assessed on each sector using the nightline method (referred to as bottom up) to the system water balance method used in this report (sometimes referred to as top-down). This gives confidence in the assumptions that have been made in the two methods. If there has been none or little active leakage control in the past it is likely that bursts will have accumulated on the system. Night flow monitoring and sectorisation can be used to identify and localise these bursts for proactive detection.

9.8 RECOMMENDATIONS

It is recommended that:

1. That revenue meter accuracy is checked by the removal and testing of a statistically significant sample of meters and a strategy developed to improve confidence in the bias and the readings and look at the economic replacement period.
2. That nightline monitoring exercises are carried out to:
    a. To target proactive leakage detection activity
    b. To confirm the benefit of leak repairs
3. The current pressure regime and the feasibility and cost of pressure management are reviewed.
4. Sectorisation is considered to assist in proactive leakage detection
5. If sectors are established then background levels of leakage are assessed in order to identify areas where long running leaks may exist.

9.9 REFERENCES

1. Losses from water Supply Systems: Standard Terminology and Recommended Performance Measures, Hirner et al, (1999) IWA Website www.iwahq.org.uk/bluepages
2. A Review of Performance Indicators for Real Losses from Water Supply Systems. Lambert A. et al (1999) AQUA, Vol. 48 No 6.
3. International comparison of water and sewerage service 2007 report. Ofwat April 2007, Ofwat website www.ofwat.gov.uk
4. Managing Leakage, Report B, Reporting Comparative Leakage Performance, WRc/UKWIR 1995
5. The new German Water Loss Regulations in context with other international applications of the IWA water balance and real loss performance indicators. R Liemberger, IWA Conference Limassol, Cyprus, November 2002
6. German National Report – Water Loss Management and Techniques. Weimer, Report to IWA World Water Congress, Berlin, October 2000
7. Accuracy limitation of the ILI – is it an appropriate indicator in developing countries? R Liemberger. IWA Conference Halifax, Canada, September 2005

Appendix 1 Standard Water Balance

<table>
<tr><th colspan="7">International Standard Components of Water Balance for Transmission or Distribution Systems</th></tr>
<tr><th colspan="7">Based on IWA Report 'Performance Indicators for Water Supply Systems', July 2000, with minor modifications;</th></tr>
<tr><td rowspan="2">Volume from Own Sources</td><td rowspan="10">System Input Volume

(corrected for known errors)</td><td>Water Exported</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied</td><td rowspan="4">Authorised Consumption</td><td rowspan="3">Billed Authorised Consumption</td><td rowspan="3">Revenue Water</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="2">Water Imported</td><td>Billed Unmetered Consumption</td></tr>
<tr><td>Unbilled Authorised Consumption</td><td rowspan="6">Non-Revenue Water</td><td>Unbilled Metered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unbilled Unmetered Consumption</td></tr>
<tr><td>Unauthorised Consumption</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Leakage on Mains</td></tr>
<tr><td>Leakage and Overflows at Storages</td></tr>
<tr><td colspan="5">Leakage on Service Connections up to point of customer metering</td></tr>
</table>

Note 1: The IWA Task Force on Performance Indicators recommends that the term 'Unaccounted for Water (UFW) is not used. If it is ever used, however, it should be defined and calculated in the same way as Non-Revenue Water (NRW) in the above table

Note 2: The 'WaterBal&PIs' , 'Consumption' and 'Running Costs' Worksheets are designed for volume data to be entered in Ml and Ml/d

Definitions of Terms

OWN SOURCES: the volume of water input to a system from the Water Supplier's own sources

WATER IMPORTED OR EXPORTED: the volumes of bulk transfers across operational boundaries

SYSTEM INPUT : the volume input to that part of the water supply system to which the water balance calculation relates, allowing for known errors. Equal to OWN SOURCES + WATER IMPORTED

WATER SUPPLIED: SYSTEM INPUT minus WATER EXPORTED

AUTHORISED CONSUMPTION: volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial and industrial purposes.

Note: *Authorised consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered*

WATER LOSSES: the difference between SYSTEM INPUT and AUTHORISED CONSUMPTION. Water losses can be considered as a total volume for the whole system, or for partial systems such as raw water mains, transmission or distribution systems, or individual zones

Note: *In the above definition of Water Losses, 'Authorised Consumption' includes bulk exports of water across operational boundaries. When doing the Water Balance calculation, a convenient alternative method of calculating Water Losses is 'Water Supplied - (Authorised Consumption - Water Exported)'*

APPARENT LOSSES: includes all types of inaccuracies associated with customer metering, plus unauthorised consumption (theft or illegal use).

Note: *Over-registration of customer meters, leads to under-estimation of REAL LOSSES. Under-registration of customer meters, leads to over-estimation of REAL LOSSES.*

REAL LOSSES: physical water losses from the pressurised system, up to the point of measurement of customer use. The annual volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks, bursts and overflows

Note: *Although physical losses after the point of customer flow measurement or assumed consumption are excluded from the assessment of REAL LOSSES, this does not necessarily mean that they are not significant or worthy of attention for demand management purposes*

REVENUE WATER: those components of SYSTEM INPUT which are billed and produce revenue (also known as BILLED AUTHORISED CONSUMPTION). Equal to BILLED WATER EXPORTED, BILLED METERED CONSUMPTION and BILLED UNMETERED CONSUMPTION

NON- REVENUE WATER: those components of SYSTEM INPUT which are not billed and do not produce revenue. Equal to UNBILLED AUTHORISED CONSUMPTION, APPARENT LOSSES and REAL LOSSES

UNBILLED AUTHORISED CONSUMPTION: those components of AUTHORISED CONSUMPTION which are not billed and do not produce revenue. Equal to UNBILLED METERED CONSUMPTION and UNBILLED UNMETERED CONSUMPTION

Appendix 2 - AWWA Water Audit Software Worksheet for '06

AWWA WLCC Water Audit Software: Reporting Worksheet

WASv3.0

Back to Instructions

? Click to access definition

Water Audit Report for: City of Guelph
Reporting Year: 2006

Please enter data in the white cells below. Where possible, metered values should be used; if metered values are unavailable please estimate a value. Indicate this by selecting a choice from the gray box to the left, where M = measured (or accurately known value) and E = estimated.

All volumes to be entered as: MEGALITRES (THOUSAND CUBIC METRES) PER YEAR

WATER SUPPLIED

Volume from own sources:	M	18,756.338	Megalitres/yr (or ML/Yr)	
Master meter error adjustment:	E	174.434	under-registered	ML/Yr
Water imported:			ML/Yr	
Water exported:			ML/Yr	
WATER SUPPLIED:		18,930.772	ML/Yr	

AUTHORIZED CONSUMPTION

Click ? for help using option buttons below

				Pcnt:	Value:
Billed metered:	M	15,923.355	ML/Yr		
Billed unmetered:	E	15.912	ML/Yr		
Unbilled metered:			ML/Yr		
Unbilled unmetered:		53.973	ML/Yr		53.973
AUTHORIZED CONSUMPTION:		15,993.240	ML/Yr		

Use buttons to select percentage OR value

				Pcnt:	Value:
WATER LOSSES (Water Supplied - Authorized Consumption)		2,937.532	ML/Yr		
Apparent Losses					
Unauthorized consumption:	E	94.652	ML/Yr		94.652
Customer metering inaccuracies:	E	773.875	ML/Yr		773.875
Systematic data handling errors:		0.000	ML/Yr		
Apparent Losses:		868.527	ML/Yr		
Real Losses					
Real Losses = (Water Losses - Apparent Losses):		2,069.005	ML/Yr		
WATER LOSSES:		2,937.532	ML/Yr		

NON-REVENUE WATER

NON-REVENUE WATER:		2,991.505	ML/Yr

SYSTEM DATA

Length of mains:	E	517.0	kilometers	
Number of active AND inactive service connections:	M	34,065		
Connection density:		66	conn./km main	
Average length of customer service line:	E	9.8	metres	(pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	E	42.0	metres (head)	

COST DATA

Total annual cost of operating water system:	E	$3,542,937	$/Year
Customer retail unit cost (applied to Apparent Losses):	M	$0.69	$/1000 litres
Variable production cost (applied to Real Losses):	M	$61.20	$/Megalitre

DATA REVIEW - Please review the following information and make changes above if necessary:

- Input values should be indicated as either measured or estimated. You have entered:
  - 5 as measured values
  - 8 as estimated values
  - 0 as default values
  - 5 without specifying measured, estimated or default
- Water Supplied Data: No problems identified
- Unbilled unmetered consumption: No problems identified
- Unauthorized consumption: No problems identified
- It is important to accurately measure the master meter - you have entered the measurement type as: measured
- Cost Data: No problems identified

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume:	15.8%
Non-revenue water as percent by cost:	20.6%
Annual cost of Apparent Losses:	$599,284
Annual cost of Real Losses:	$126,623

Operational Efficiency Indicators

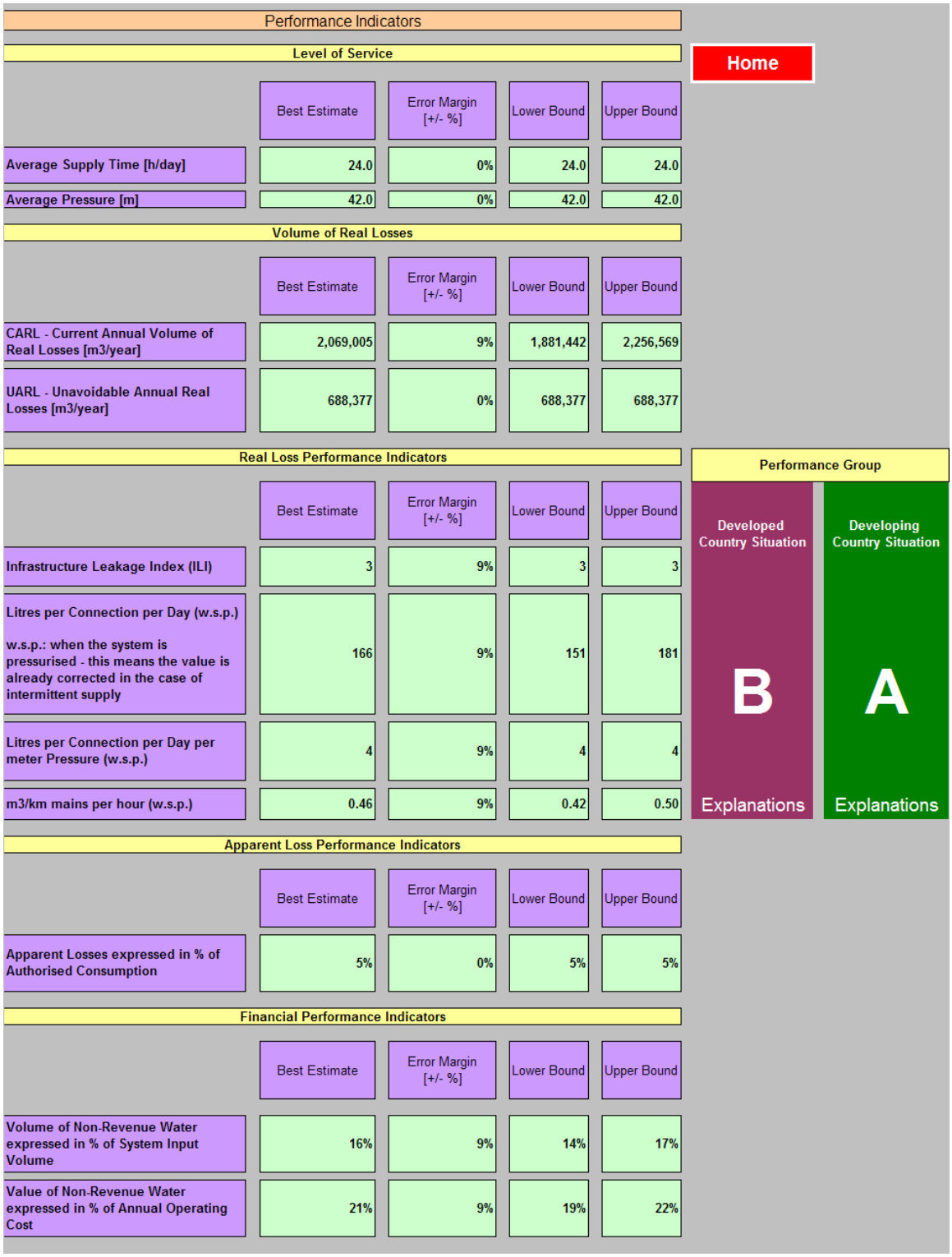
Apparent Losses per service connection per day:	69.85	litres/connection/day
Real Losses per service connection per day*:	166.40	litres/connection/day
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per meter (head) pressure:	3.96	litres/connection/day/m
? Unavoidable Annual Real Losses (UARL):	688.38	cubic meters/year
? Infrastructure Leakage Index (ILI) [Real Losses/UARL]:	3.01	

* only the most applicable of these two indicators will be calculated

Appendix 3 – AWWA Water Audit Software Water Balance for '06

<table>
<tr><td colspan="5">AWWA WLCC Water Audit Software: Water Balance
<small>Copyright © 2006, American Water Works Association. All Rights Reserved.</small> WASv3.0</td><td>Water Audit Report For:
City of Guelph</td><td>Report Yr:
2006</td></tr>
<tr><td rowspan="8">Own Sources
(Adjusted for known errors)
18,930.772</td><td rowspan="8">Water Supplied
18,930.772</td><td rowspan="4">Authorized Consumption
15,993.240</td><td rowspan="2">Billed Authorized Consumption
15,939.267</td><td>Billed Metered Consumption (inc. water exported)
15,923.355</td><td rowspan="2">Revenue Water
15,939.267</td></tr>
<tr><td>Billed Unmetered Consumption
15.912</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
53.973</td><td>Unbilled Metered Consumption
0.000</td><td rowspan="2">Non-Revenue Water (NRW)
2,991.505</td></tr>
<tr><td>Unbilled Unmetered Consumption
53.973</td></tr>
<tr><td rowspan="4">Water Losses
2,937.532</td><td rowspan="2">Apparent Losses
868.527</td><td>Unauthorized Consumption
94.652</td></tr>
<tr><td>Customer Metering Inaccuracies
773.875</td></tr>
<tr><td rowspan="2">Real Losses
2,069.005</td><td>Systematic Data Handling Errors
0.000</td></tr>
<tr><td>Leakage on Transmission and/or Distribution Mains
Not broken down</td></tr>
<tr><td>Water Imported
0.000</td><td colspan="3">Leakage and Overflows at Utility's Storage Tanks
Not broken down</td></tr>
<tr><td colspan="3">Leakage on Service Connections
Not broken down</td></tr>
</table>

Appendix 4 – WB-EasyCalc Performance Indicators for '06



Performance Indicators

Level of Service

Home

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Average Supply Time [h/day]	24.0	0%	24.0	24.0
Average Pressure [m]	42.0	0%	42.0	42.0

Volume of Real Losses

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
CARL - Current Annual Volume of Real Losses [m3/year]	2,069,005	9%	1,881,442	2,256,569
UARL - Unavoidable Annual Real Losses [m3/year]	688,377	0%	688,377	688,377

Real Loss Performance Indicators

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Infrastructure Leakage Index (ILI)	3	9%	3	3
Litres per Connection per Day (w.s.p.) w.s.p.: when the system is pressurised - this means the value is already corrected in the case of intermittent supply	166	9%	151	181
Litres per Connection per Day per meter Pressure (w.s.p.)	4	9%	4	4
m3/km mains per hour (w.s.p.)	0.46	9%	0.42	0.50

Performance Group

Developed Country Situation	Developing Country Situation
B	A
Explanations	Explanations

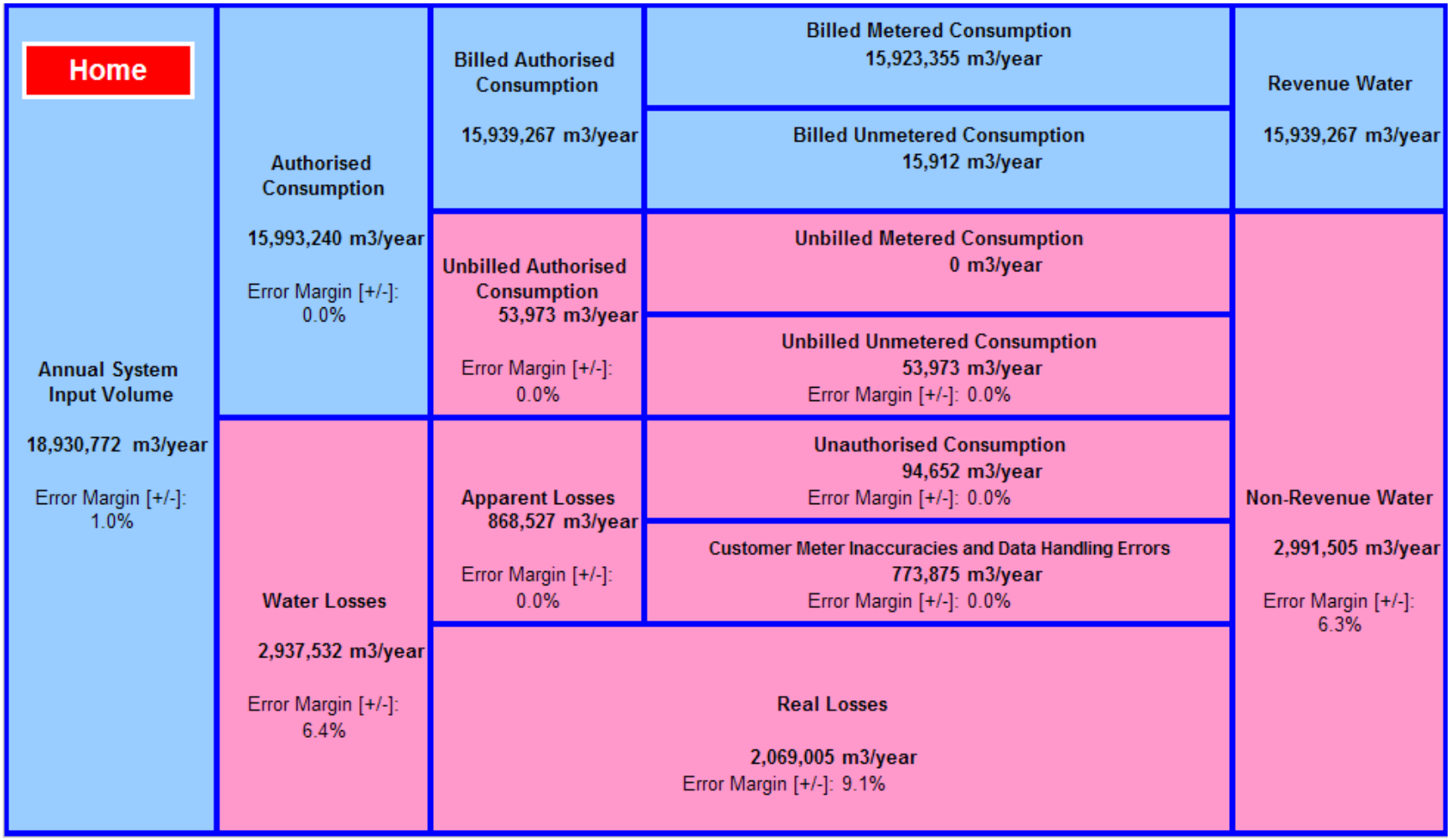
Apparent Loss Performance Indicators

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Apparent Losses expressed in % of Authorised Consumption	5%	0%	5%	5%

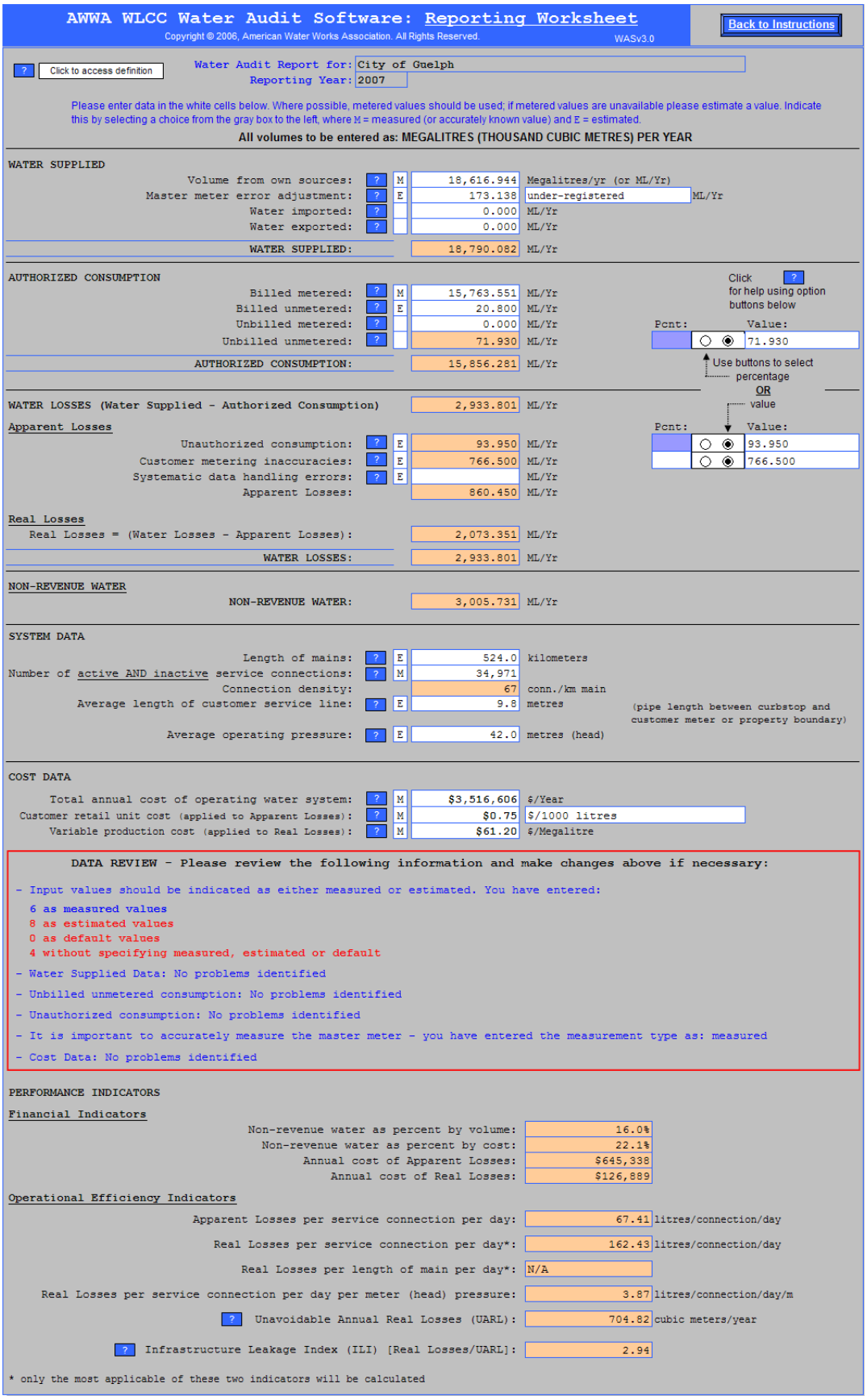
Financial Performance Indicators

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Volume of Non-Revenue Water expressed in % of System Input Volume	16%	9%	14%	17%
Value of Non-Revenue Water expressed in % of Annual Operating Cost	21%	9%	19%	22%

Appendix 5 – WB EasyCalcs Worksheet for '06



Appendix 6 – Water Audit Software Worksheet for '07



AWWA WLCC Water Audit Software: Reporting Worksheet

Copyright © 2006, American Water Works Association. All Rights Reserved. WASv3.0

Back to Instructions

? Click to access definition

Water Audit Report for: City of Guelph
Reporting Year: 2007

Please enter data in the white cells below. Where possible, metered values should be used; if metered values are unavailable please estimate a value. Indicate this by selecting a choice from the gray box to the left, where M = measured (or accurately known value) and E = estimated.

All volumes to be entered as: MEGALITRES (THOUSAND CUBIC METRES) PER YEAR

WATER SUPPLIED

Volume from own sources:	M	18,616.944	Megalitres/yr (or ML/Yr)	
Master meter error adjustment:	E	173.138	under-registered	ML/Yr
Water imported:		0.000	ML/Yr	
Water exported:		0.000	ML/Yr	
WATER SUPPLIED:		18,790.082	ML/Yr	

AUTHORIZED CONSUMPTION

Click ? for help using option buttons below

				Pcnt:	Value:
Billed metered:	M	15,763.551	ML/Yr		
Billed unmetered:	E	20.800	ML/Yr		
Unbilled metered:		0.000	ML/Yr		
Unbilled unmetered:		71.930	ML/Yr		71.930
AUTHORIZED CONSUMPTION:		15,856.281	ML/Yr		

Use buttons to select percentage OR value

				Pcnt:	Value:
WATER LOSSES (Water Supplied - Authorized Consumption)		2,933.801	ML/Yr		
Apparent Losses					
Unauthorized consumption:	E	93.950	ML/Yr		93.950
Customer metering inaccuracies:	E	766.500	ML/Yr		766.500
Systematic data handling errors:	E		ML/Yr		
Apparent Losses:		860.450	ML/Yr		
Real Losses					
Real Losses = (Water Losses - Apparent Losses):		2,073.351	ML/Yr		
WATER LOSSES:		2,933.801	ML/Yr		

NON-REVENUE WATER

NON-REVENUE WATER:	3,005.731	ML/Yr	

SYSTEM DATA

Length of mains:	E	524.0	kilometers	
Number of active AND inactive service connections:	M	34,971		
Connection density:		67	conn./km main	
Average length of customer service line:	E	9.8	metres	(pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	E	42.0	metres (head)	

COST DATA

Total annual cost of operating water system:	M	$3,516,606	$/Year
Customer retail unit cost (applied to Apparent Losses):	M	$0.75	$/1000 litres
Variable production cost (applied to Real Losses):	M	$61.20	$/Megalitre

DATA REVIEW - Please review the following information and make changes above if necessary:

- Input values should be indicated as either measured or estimated. You have entered:
  - 6 as measured values
  - 8 as estimated values
  - 0 as default values
  - 4 without specifying measured, estimated or default
- Water Supplied Data: No problems identified
- Unbilled unmetered consumption: No problems identified
- Unauthorized consumption: No problems identified
- It is important to accurately measure the master meter - you have entered the measurement type as: measured
- Cost Data: No problems identified

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume:	16.0%	
Non-revenue water as percent by cost:	22.1%	
Annual cost of Apparent Losses:	$645,338	
Annual cost of Real Losses:	$126,889	

Operational Efficiency Indicators

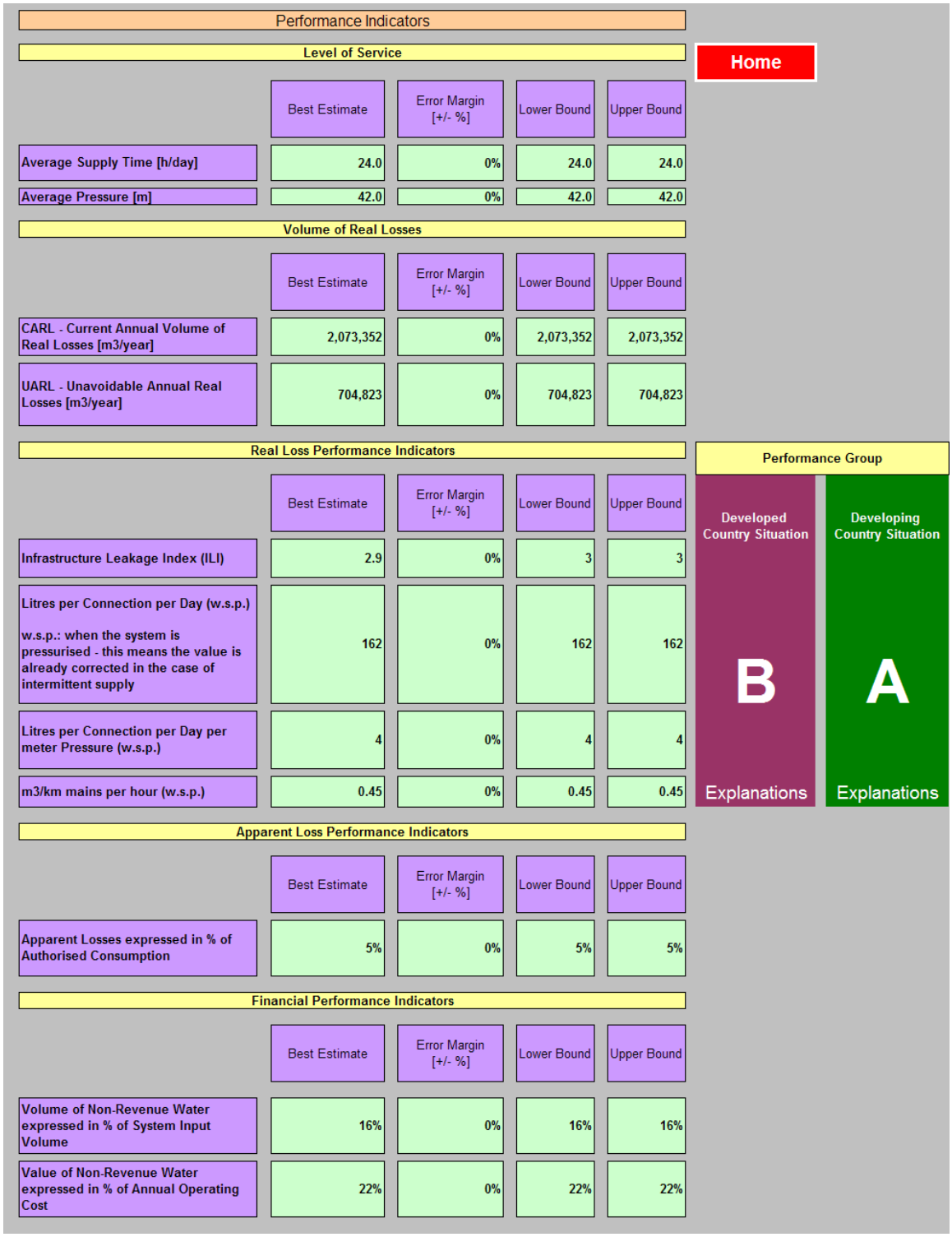
Apparent Losses per service connection per day:	67.41	litres/connection/day
Real Losses per service connection per day*:	162.43	litres/connection/day
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per meter (head) pressure:	3.87	litres/connection/day/m
? Unavoidable Annual Real Losses (UARL):	704.82	cubic meters/year
? Infrastructure Leakage Index (ILI) [Real Losses/UARL]:	2.94	

* only the most applicable of these two indicators will be calculated

Appendix 7 – AWWA Water Audit Software Water Balance for '07

AWWA WLCC Water Audit Software: Water Balance						Water Audit Report For:	Report Yr:
Copyright © 2006, American Water Works Association. All Rights Reserved. WASv3.0						City of Guelph	2007
	Water Exported 0.000	Billed Water Exported					
Own Sources (Adjusted for known errors) 18,790.082	Water Supplied 18,790.082	Authorized Consumption 15,856.281	Billed Authorized Consumption 15,784.351	Billed Metered Consumption (inc. water exported) 15,763.551	Revenue Water 15,784.351		
				Billed Unmetered Consumption 20.800			
			Unbilled Authorized Consumption 71.930	Unbilled Metered Consumption 0.000	Non-Revenue Water (NRW) 3,005.731		
				Unbilled Unmetered Consumption 71.930			
		Water Losses 2,933.801	Apparent Losses 860.450	Unauthorized Consumption 93.950			
				Customer Metering Inaccuracies 766.500			
				Systematic Data Handling Errors 0.000			
Water Imported 0.000			Real Losses 2,073.351	Leakage on Transmission and/or Distribution Mains Not broken down			
				Leakage and Overflows at Utility's Storage Tanks Not broken down			
				Leakage on Service Connections Not broken down			

Appendix 8 – WB EasyCalc Performance Indicators for '07



Performance Indicators

Level of Service

Home

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Average Supply Time [h/day]	24.0	0%	24.0	24.0
Average Pressure [m]	42.0	0%	42.0	42.0

Volume of Real Losses

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
CARL - Current Annual Volume of Real Losses [m3/year]	2,073,352	0%	2,073,352	2,073,352
UARL - Unavoidable Annual Real Losses [m3/year]	704,823	0%	704,823	704,823

Real Loss Performance Indicators

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Infrastructure Leakage Index (ILI)	2.9	0%	3	3
Litres per Connection per Day (w.s.p.) w.s.p.: when the system is pressurised - this means the value is already corrected in the case of intermittent supply	162	0%	162	162
Litres per Connection per Day per meter Pressure (w.s.p.)	4	0%	4	4
m3/km mains per hour (w.s.p.)	0.45	0%	0.45	0.45

Performance Group

Developed Country Situation	Developing Country Situation
B	A
Explanations	Explanations

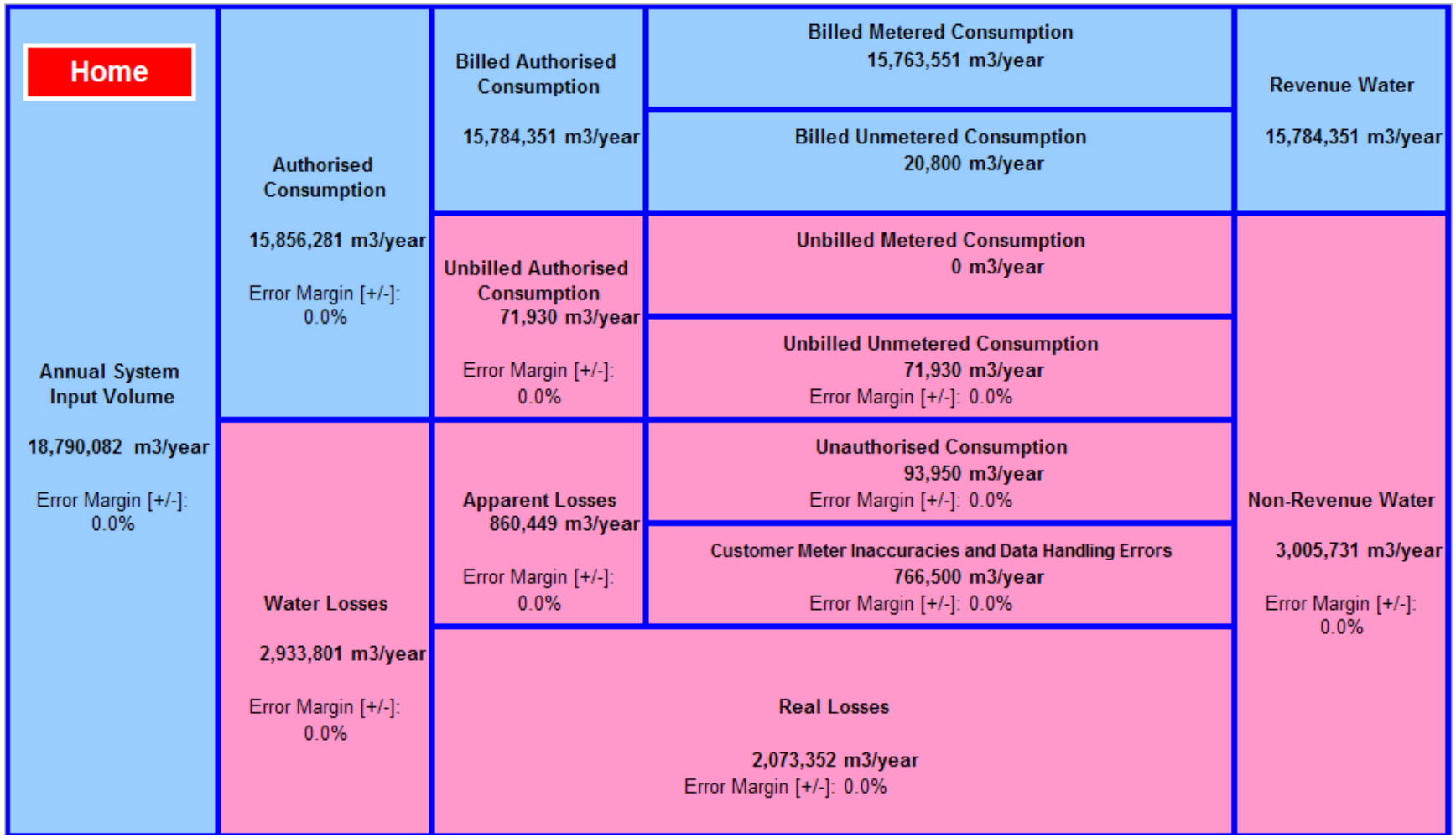
Apparent Loss Performance Indicators

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Apparent Losses expressed in % of Authorised Consumption	5%	0%	5%	5%

Financial Performance Indicators

	Best Estimate	Error Margin [+/- %]	Lower Bound	Upper Bound
Volume of Non-Revenue Water expressed in % of System Input Volume	16%	0%	16%	16%
Value of Non-Revenue Water expressed in % of Annual Operating Cost	22%	0%	22%	22%

Appendix 9 WB-EasyCalc Water Balance for '07



Appendix 10 - Dave Pearson's Water Balance for Guelph '06

IWA Water Balance and Performance Indicators

Date: **13/06/2008**

Study Area: **Guelph**

Input by: **DP**

Study Period: **April 06 - Mar 07**

Key: Data entry / Other Sheet

Water Balance				Av daily Volume Ml/d	95% Confidence	Variance
Water produced at treatment works	Meter **over** registration	-0.93%		51.9	1%	0.070
Water Imported	Meter **over** registration	0.00%		0.00	1%	0.000
	System Input Volume			51.85	1%	0.070
Water Exported	Meter **over** registration	0.00%		0.00	4%	0.000
	Water Supplied			51.85	1%	0.070
Billed Household Metered						0.000
Billed Non-Household Metered						0.000
Billed Metered consumption				43.64	2%	0.198
Billed Unmetered consumption				0.04	20%	0.000
	Revenue Water/Billed Authorised Consumption			43.68	2%	0.198
	Non-Revenue Water			8.17	12%	0.268
Unbilled authorised metered consumption				0.00	20%	0.000
Unbilled authorised unmetered consumption				0.15	30%	0.000
	Unbilled Authorised			0.15	30%	0.000
	Authorised consumption			43.83	2%	0.199
	Water Loss			8.03	13%	0.269
Household metering losses	Meter **under** registration			0.00		0.000
Non Household metering losses	Meter **under** registration			0.00		0.000
	Meter **under** registration	4.63%		2.12	25%	0.073
Unbilled unauthorised consumption		0.50%		0.26	100%	0.017
	Apparent Losses			2.4	25%	0.091
	Real Losses (CARL)			5.6	21%	0.359

Network data		Value	95% Confidence	
Length of mains	km	517	2%	27.83
Number of connections	no	34065	3%	271861
Number of services	no	34065	2%	120827
Connection ratio		1.0	4%	0.000
Connection density	no/km	66	4%	1.469
Av length of UGSP	m	9.8	10%	0.25
Total UGSP length	km	334	10%	302
Average Pressure	psi	60	10%	9.37
	m	42	10%	4.63
Hour to Day Factor	hrs	24	10%	1.50

UARL	Ml/d	95% Confidence	
Mains	0.39	10%	0.0004
Connections	1.15	10%	0.0037
Properties	0.35	14%	0.0007
Total	1.9	7%	0.0048

IWA System Performance Indicators				95% Confidence	
Non Revenue Water		% of SIV	16%	12%	0.000
		% of WS	16%	12%	0.000
Real Losses	TIRL	l/conn/d	170	20%	316
Real Losses	ILI		3.0	22%	0.112

Appendix 11 - Dave Pearson's Water Balance for Guelph 2007

IWA Water Balance and Performance Indicators

				Date	**13/06/2008**	
Study Area	**Guelph**			Input by:	**DP**	
Study Period	**April 07 - Mar 08**			Key	Data entry	
					Other Sheet	
Water Balance				**Av daily Volume Ml/d**	**95% Confidence**	**Variance**
Water produced at treatment works		Meter **over** registration	-0.93%	51.5	1%	0.069
Water Imported		Meter **over** registration	0.00%	0.00	1%	0.000
	System Input Volume			51.48	1%	0.069
Water Exported		Meter **over** registration	0.00%	0.00	4%	0.000
	Water Supplied			51.48	1%	0.069
Billed Household Metered						0.000
Billed Non-Household Metered						0.000
Billed Metered consumption				43.19	2%	0.194
Billed Unmetered consumption				0.06	20%	0.000
	Revenue Water/Billed Authorised Consumption			43.24	2%	0.194
	Non-Revenue Water			8.23	12%	0.263
Unbilled authorised metered consumption				0.00	20%	0.000
Unbilled authorised unmetered consumption				0.19	30%	0.001
	Unbilled Authorised			0.19	30%	0.001
	Authorised consumption			43.44	2%	0.195
	Water Loss			8.04	13%	0.264
Household metering losses		Meter **under** registration		0.00		0.000
Non Household metering losses		Meter **under** registration		0.00		0.000
		Meter **under** registration	4.63%	2.10	25%	0.072
Unbilled unauthorised consumption		Default AWWA%WS	0.50%	0.26	100%	0.017
	Apparent Losses			2.4	25%	0.089
	Real Losses (CARL)			5.7	20%	0.353

Network data		Value	**95% Confidence**	
Length of mains	km	524	2%	28.59
Number of connections	no	34971	3%	286514
Number of services	no	34971	2%	127340
Connection ratio		1.0	4%	0.000
Connection density	no/km	67	4%	1.507
Av length of UGSP	m	9.8	10%	0.25
Total UGSP length	km	343	10%	318
Average Pressure	psi	60	10%	9.37
	m	42	10%	4.63
Hour to Day Factor	hrs	24	10%	1.50

UARL	**Ml/d**	**95% Confidence**	
Mains	0.40	10%	0.0004
Connections	1.18	10%	0.0040
Properties	0.36	14%	0.0007
Total	1.9	7%	0.0051

IWA System Performance Indicators				**95% Confidence**	
Non Revenue Water		% of SIV	16%	12%	0.000
		% of WS	16%	12%	0.000
Real Losses	TIRL	l/conn/d	160	21%	295
Real Losses	ILI		2.9	22%	0.105